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Nature of the $\Lambda(1405)$ resonance

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The $\Lambda(1405)$ resonance lies just below the K^-p threshold at 1432 MeV. Hence, the kaon-nucleon interactions offer an appropriate means to study the nature of this resonance.

However, investigating the strong multichannel K^--proton reactions, implies studying *simultaneously* the following eight channels:

$$K^-\ p \rightarrow K^-\ p,\ \overline{K^0} - n,\ \Sigma^+\pi^-,\ \Sigma^0\pi^0,\ \Sigma^-\pi^+,\ \Lambda\pi^0,\ \Lambda\gamma,\ \Sigma^0\gamma.$$

In the literature, the $\Lambda(1405)$ is considered as an s-channel resonance or as a quasi-bound $(\overline{K}N, \Sigma\pi)$ state. In the quark-model approaches, this hyperon is considered as a pure q^3 state, a quasi-bound $\overline{K}$N state or still as a hybrid $(q^3{+}q^4\overline{q}\cdots)$ state. A number of potential model fits to the scattering data incorporate the $\Lambda(1405)$ as a quasi-bound $(\overline{K}N, \Sigma\pi)$ resonance. Very recent approaches introduce this Λ hyperon as an "elementary" field through chiral perturbation theory, as a quasi-bound state generated via a potential from chiral dynamics or consider it to be composed of a SU(2) soliton and a kaon bound in a S-wave.

Much experimental and theoretical effort has been expended to understand this system. Close to the threshold (*i.e.* $p_K \leq 200 MeV/c$), there are roughly 70 total cross section data points for the six strong interaction scattering processes. Besides, the following threshold branching ratios have been measured with high accuracy:

$$\gamma = \frac{\Gamma(K^-p\rightarrow\pi^+\Sigma^-)}{\Gamma(K^-p\rightarrow\pi^-\Sigma^+)},\ R_c = \frac{\Gamma(K^-p\rightarrow charged\ particles)}{\Gamma(K^-p\rightarrow all)},\ R_n = \frac{\Gamma(K^-p\rightarrow\pi^0\Lambda)}{\Gamma(K^-p\rightarrow\ all\ neutral\ states)},$$

$$R_{\Lambda\gamma} = \frac{\Gamma(K^-p\rightarrow\Lambda\gamma)}{\Gamma(K^-p\rightarrow all)},\ R_{\Sigma\gamma} = \frac{\Gamma(K^-p\rightarrow\Sigma^0\gamma)}{\Gamma(K^-p\rightarrow all)}.$$

A general coupled-channel formalism for *both* strong and electromagnetic channels using a particle basis is developed and applied to all the low energy K^-p data with the exception of the *1s* atomic level shift.

We find a number of good fits in which the coupling constants were close to their expected SU(3) values. In all of the fits, the $\Lambda(1405)$ is produced as a *bound* $\overline{K}N(\Sigma\pi)$ *resonance*, and the initial state interactions were very important for the radiative capture branching ratios. The ratio $R_{\Lambda\gamma}$ varies roughly by a factor of 2, and the ratio $R_{\Sigma\gamma}$ by more than a factor of 10 due to the initial state interactions.

Another crucial quest concerns the scattering length. Our results tend to show that the measured electromagnetic branching ratios and the extracted scattering length from the *1s* atomic level shift are not compatible and can not be reproduced *simultaneously*. Our predictions underline clearly the need for more experimental investigations.